MAGSAT

NASA (U.S.) scientific satellite (1979-1980) made the first precise, globally distributed measurements of the vector magnetic field near Earth. From an altitude of 300-550 km, the space domain representation of the internal field extended from spherical harmonic (q.v.) degrees 1 through 36 for the vector field (Lowe et al., 2001), with additional resolution to degree 65 for the total field (Sabaka et al., 2002). Magsat also contributed significantly to understanding of the ionospheric magnetic field, and the meridional current systems through which the satellite flew. Magsat was preceded by the POGO (q.v.) satellites that precisely measured the earth's scalar magnetic field from altitudes as low as 400 km. Magnetic field measurements have been made from near-earth space since 1958, when Sputnik 3 (USSR) collected fluxgate magnetometer measurements of the field with accuracies of about 100 nT. Magsat's measurements of the near-earth vector field were not improved upon, or even repeated, until the launchings of Ørsted (q.v) (1999) and CHAMP (q.v.) (2000), led by Denmark and Germany, respectively. Follow-on magnetic field missions by NASA focused on planetary magnetic fields (e.g. Mercury, Venus, Mars, and the outer planets), on the earth's magnetosphere, and the dynamics of the high-latitude ionosphere.

The Magsat project scientist was Robert A. Langel (q.v.), the project manager was Gilbert Ousley, and the spacecraft design, development and testing was done by the Applied Physics Laboratory (APL) of John Hopkins University. The vector magnetometer was designed and built at Goddard Space Flight Center's Laboratory for Extraterrestrial Physics by Mario Acuña (Instrument Scientist) and his group. Scientists and scientific organizations in the US, Europe, and Japan formed the largest group of users of Magsat observations. Magsat weighed 182 kg, and cost 19.2 million US dollars from inception through production of the finished data products. Magsat was modeled on the Small Astronomical Satellite (SAS-3), built by APL in 1975. SAS-3 utilized a Doppler tracking system for position determination to within 60 m vertically and 200 m horizontally, and had two star trackers that could provide attitude information to 10 arc-seconds. However, the magnetic fields associated with these star trackers and the spacecraft itself would have introduced unacceptably large errors into the magnetic field determinations. Therefore, a deployable scissors boom and an infrared attitude transfer system (ATS) were developed for Magsat that put the scalar and vector magnetometers six meters away from the star trackers, and the body of the spacecraft (Figure 1). The deployable boom was designed, developed, and tested by APL, and the attitude transfer system was based on one used for submarines and adapted for Magsat by the Barnes Engineering Company. The sun-synchronous orbit of Magsat, resulting in a sampling of the magnetic field only at dawn and dusk local time, was a compromise dictated by the carrying capacity of the Scout launch vehicle. The chosen orbit, and mission lifetime (Fall, 1979 through Spring, 1980) allowed for a maximum exposure of the fixed solar array to the sun, a near-constant thermal environment, and a fixed flight attitude that allowed the star trackers to always face away from the earth.

The orientation of the vector magnetometer was determined, at 0.25 s intervals, using the two star cameras. If only one star camera was tracking an identified star, a precision sun sensor immediately adjacent to the vector magnetometer was used instead. Jumps in the vector data of 10-15 nT can occur at locations where the method of determining the orientation of the vector magnetometer changes. The system for transferring the attitude determined by the star camera on the spacecraft body to the vector magnetometer on the end of the boom involved two optical systems, one for pitch and yaw (utilizing a plane mirror), and a second for roll (using a dihedral mirror). As predicted, the system for measuring roll had the largest errors, estimated at about 8 times the pitch/yaw error.

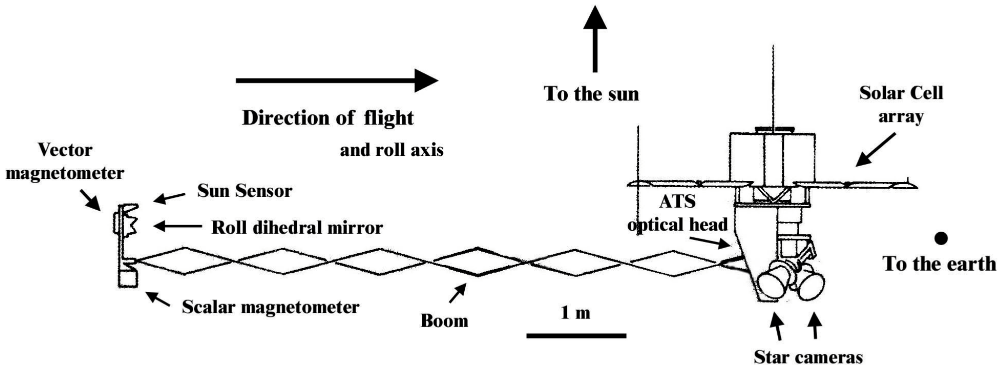

Figure 1. Line drawing of Magsat, it's orientation, and critical systems

Magsat carried both scalar and vector magnetometers. The scalar magnetometer, a two-sensor, cesium 133 vapor optically pumped magnetometer, was used to calibrate the vector magnetometer. The two-sensor arrangement was chosen to minimize null zones, where the magnetometers are incapable of sensing the ambient field. In practice, intermittent noise in the cesium lamp excitation circuits caused the tracking filters to lose lock, and reduced the amount of data returned to well below the nominal 8 Hz rate. System errors in the determination of the scalar field were 0.5 to 1.5 nT. The vector instrument was a triaxial fluxgate magnetometer with a dynamic range of +-2000 nT, and digitally controlled current sources to increase its range to +-64000 nT. The vector instrument sampled the ambient field 16 times/second with a resolution of +-0.5 nT. Each of the three orthogonal sensors was wound with platinum wire on a highly permeable toroidal magnetic core. The sensors were mounted on a stable ceramic block and temperature controlled to minimize alignment shifts with respect to the reference mirrors of the attitude transfer system.

Each observation has associated with it an attitude uncertainty, and details on the sensors that were used to calculate the attitude. The mission requirements specified that the three axes of the vector magnetometer be determined within 60 arc-seconds, although in practice it was often known within 20 arc-seconds, corresponding to an attitude error of 5 nT. A detailed error budget can be found in Langel and Hinze (1998) as Table 3.4. The observations can be accessed through the National Space Science Data Center, for example at http://nssdc.gsfc.nasa.gov/ftphelper/magsat.html

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Cross References

Langel, R.A., Champ, Ørsted, POGO, Spherical Harmonics

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